

State, Univ. of New York
Research Foundation
Albany.

REMOTE SENSING
AN INVENTORY OF EARTH'S RESOURCES

In the 1950's, the national conscience was set astir by the warnings in Rachel L. Carson's Silent Spring. Individuals at first, followed later by large organizations, began to question the manner in which we were using and abusing our environment. Pitched battles were raised by those interest groups who encouraged uncontrolled growth in the economic and industrial sectors to support a burgeoning population, while their antagonists argued that the world, let alone the United States, did not have the resources needed to supply the wants of a runaway economic and population boom. As in most complex problems, the solutions are also complex. Consider the statement made by a U.S. Senator in the early 1970's:

"Between now and the year 2000, we must build again all that we have built before. We must build as many homes, schools, and hospitals in the next three decades as we built in the previous three centuries."

Please note that the Senator did not say, "we may or might have to build" when forecasting our country's needs in the decades ahead. It appears that we have no choice in the matter. Entirely new cities and towns will be constructed in places where rural and suburban areas now exist. In view of the dwindling world wide oil reserves, we most certainly cannot build as we have in the past, without regard for the need of mass transportation. Many major questions related to the need of construction must be answered. Where will these new cities go in a country where 75% of the population

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lives on only 2% of the land? Should we simply add on to those cities already existing? What will be the source of energy chosen to power industry and homes? Where will the additional fresh water and food come from? How and where will we dispose of the waste created by our hundreds of millions of citizens?

The answers to these and hundreds of other questions can be found through the vigorous application of our recently acquired technology. It was, in fact, a view from a spacecraft window by an Apollo astronaut that led to a concept of our world not realized prior to manned spaceflight. The concept has come to be known as the "Spaceship Earth" analogy - a model which aptly describes our world, in its present state of limited air, water, food, and available living space.

To help in gathering some of the information needed to make the best possible plans, the National Aeronautics and Space Administration (NASA) designed a system of data acquisition and interpretation unlike any in existence. Known to the world as the Earth Resources Technology Satellite system or simply ERTS, it has proven to be a very powerful tool in extending our perception of ourselves and our planet Earth. In order to make the data come alive and be used by society for the general benefit of mankind, rather than be a little known esoteric study sitting on a few shelves, NASA has brought together many of the nation's agencies and institutions,

private industry, and universities. In all, 310 principal investigators are examining the information returned to Earth by ERTS. In this number are included scientists from agronomists to astronomers; social scientists, geographers, educators, and engineers.

ERTS is an ultrarefinement of the technique of "remote sensing", i.e., studying a subject from a distance, which had its beginnings about 115 years ago. In 1858 the French experimenter G.F. Tournachon suspended himself in a balloon high above the city of Paris. While dangling precariously, he managed to photograph the city below. He had made many attempts at the same feat in the months preceding but had not achieved success. Though taking a photograph today is a trivial event, it should be remembered that in Tournachon's day, the photographer had to perform the entire photographic process himself. He was finally rewarded with a picture of Paris which gave the inhabitants an unique perspective of their city.

The art of remote sensing through aerial photography was refined as a result of its use during the twentieth century's numerous wars. The recent development of two technological advancements have allowed us to carry the science of surveillance to unimagined heights. The first of these advances was the creation of extremely fast and versatile computers which literally can be taught to interpret photographs with great precision. The sec-

ond forward leap was the advent of men in space. The astronauts piloting the Mercury and Gemini spacecraft took hand-held cameras into orbit and delivered the photographs into the hands of ground-based scientists. These photographs, with their wide scope and rich colors, showed for the first time the uncluttered big picture of our planet. More than 6,000 photographs were ultimately taken by the Mercury and Gemini astronauts. This program of men taking pictures of the Earth from orbit was enlarged during the Apollo series and reached its apex during the operation known as "Skylab".

ERTS was launched into a near polar, 570 mile high orbit on July 23, 1972. This orbit allows the butterfly-shaped spacecraft to cross the equator, moving north to south, fourteen times daily at 0942, local time.

Insert Picture #1 in this place.

The Multispectral Scanner Subsystem (MSS) carried by ERTS collects radiation reflected into space by the Earth, records it on magnetic tape, then transmits it to ground-based antennas. All signals from the satellite are eventually routed to the Goddard Space Flight Center in Greenbelt, Maryland, where they are processed.

The mechanics of the orbit result in the spacecraft passing over any given part of the Earth every eighteen days. This repetitive coverage provides the Earthbound investigators with the ability to view the same area every eighteen days, weather permitting, throughout the year. Seasonal changes, planting and harvesting of crops, land use changes, forestry activities, effects of floods,

forest fires, and many other repeating and transient phenomena can be studied easily and profitably.

The information gathered by ERTS is meant to benefit our lives. Thus, the satellite must be able to gather data on our surroundings, our cities, water resources, agricultural and forest lands, as well as other potentially beneficial areas such as previously unknown mineral and energy resources. The satellite must also be able to detect major sources of the pollution of land and water. The key to selecting the best way of remotely sensing the Earth lies in the manner in which sunlight interacts with the air and the surface of the Earth prior to some of the solar energy being reflected back into space.

Insert Picture #2 here: The Electromagnetic Spectrum:
The spectrum of energy produced by the Sun ranges from the very energetic gamma rays down to the least energetic radio waves. The visible region of the spectrum, expanded for easy viewing, comprises but a small part of the total spectrum of energy.

The spectrum of radiant energy produced by the Sun interacts quite strongly with the Earth's atmosphere, with most of the higher energy being absorbed far above the ground. We see only a small amount of the energy that reaches the surface of the Earth although we can use photographic and electronic means to sense the other radiations. Since the ultraviolet, violet, and blue regions of the spectrum are scattered and absorbed by the dust particles and water vapor in the atmosphere they would not be well suited to the task of providing

the satellite's sensors with a coherent picture of the Earth below. NASA scientists selected a section of the electromagnetic spectrum occupied by the green, red, and photographic infrared waves of radiant energy, because these waves are both strongly reflected by the various constituents of the Earth's surface while at the same time being able to pass virtually unhindered into space.

When the solar radiation strikes the surface of the Earth, it is either absorbed or reflected. The physical and chemical nature of the material shined on by the Sun determines what will happen to the energy. The average green leaf, for example, reflects about 20% of the green light that hits it and absorbs the other 80%. The same leaf absorbs 95% of the red light and reflects only 5%. As for the invisible photographic infrared, 80% is reflected by the leaf, while only 20% is absorbed. Thus, in the region of the spectrum where our eyes are sensitive we see chlorophyll bearing plants as green, but compared to the brightness these plants have in the infrared, the reflected green light is a very poor second. By analogy, a green plant is as bright in the infrared as snow is when viewed by normal light. Since one of the reasons for orbiting ERTS was to examine crops and forests, it made practical sense to measure the reflected infrared energy from them as the plants appear brightest in this region of the spectrum.

The people who examine the images made from ERTS views of the Earth

use the difference in the way substances absorb and reflect solar energy as a means of identification. Just as each person possesses unique penmanship, we find that the solar energy reflected by buildings and roads, plants of different types and states of growth, sandy beach areas, and water with varying amounts of sediment loads, are also individually different. Therefore, we can use these reflected spectral signatures to locate and identify the cities, roads, forests, and lakes which dot the ERTS images.

The brightness of the vegetation recorded by the satellite depends upon several things. First, the type of vegetation: big leaves will generally be brighter than small leaves because they have more reflecting area. Grass, which is closely planted and watered, as on a golf course, will be an excellent reflector of infrared, as would a rice paddy. Hardwood trees, such as maple and oak, show up brighter than do pine trees, at least until the former lose their leaves. When viewed in the infrared, healthy plants will look brighter than diseased plants of the same type. It will be seen by examining Figure #3, which depicts patterns of reflectance of different materials, that water is a very strong absorber of the infrared, and looks black as a consequence. If the water carries suspended matter which reduces its absorption of light, then it will have a turquoise color on the ERTS images.

Cities have unique appearances on the ERTS images, standing out clear-

ly as blue-gray splotches surrounded by the red areas indicating the vegetation of the suburbs and rural areas. Within the confines of the cities themselves can be seen the reddish hues of golf courses, large parks, and cemeteries.

Insert Figure #3 in this place.

The electro-optical sensors carried by ERTS are sensitive to four regions or bands of the solar spectrum. These portions of the spectrum are called Band 4,5,6, and 7. Note that each of the substances depicted on the graph above has an unique pattern of reflectance. Although an investigator may use only certain energy bands for his work, the images provided here will be of the false color type in which vegetation will appear red. The brighter the red, the more lush the vegetation.

How is the ERTS imagery being used? The list below indicates the broad categories of use being made of the images sent to Earth by the satellite.

Land Use Surveys - Geographic Mapping: regional planning, urban development, census, and map making.

Geological and Land Form Surveys: mineral and oil exploration, earth structure, volcanoes, and erosion.

Agricultural Surveys: crop and soil classification, timber inventory, detection of plant disease.

Hydrologic Surveys: water supply, watershed management, snow and lake ice, floods.

Environmental Quality Surveys: air, water, and land pollution, wetland and estuary conservation, tundra ecology, wildlife habitats.

Ocean Surveys: coastal processes, sea ice, ocean dynamics, marine food resources, navigational hazards, and water depth.

Examination of these categories will show that they touch nearly every aspect of our lives.

Why use satellites for remote sensing?

The amount of information gathered by a team of investigators on the ground will show far greater detail than that gleaned from an aerial photograph made of the same area. The same conclusion can be derived when comparing the fineness of detail visible in imagery obtained from aircraft and satellites. However, any fine details lost by medium, high, and orbital altitudes as a result of the heights at which the vehicles operate is more than compensated by the enlarged perspective they supply. In the case of ERTS, the 18 day repetitive coverage is a highly desirable feature, and one which is impractical to duplicate without the use of satellites. For example, approximately sixty high altitude images obtained from aircraft are needed to cover the area equal to the one ERTS image. In order to check the interpretations made from studying the satellite images, teams of scientists station themselves at preselected sites over which the satellite will pass. As ERTS orbits above, recording the scene by use of the MSS, the scientists at the site will make similar observations. Later, the data gathered by the two techniques will be compared for the purpose of noting any differences.

The information gathered by the scientists in the area scanned by the satellite is known as ground truth data and is extremely useful to investigators studying ERTS images of areas inaccessible to scientists.

Hopefully, as a result of your use of the sample of ERTS images selected for this presentation, you will become familiar with many regions of the United States which may presently be only names and places found on the pages of an atlas. Of the more than 30,000 images received from ERTS, only six have been chosen to represent the many categories of study listed previously.

Insert Picture #4 in this place.

These images represent East and West coast population centers, a midwestern city built at the confluence of three great rivers, the coal rich mountains of the East, and the timbered mountains of the American Northwest. The selected sites are: A. Metropolitan New York - Philadelphia; B. Southeastern Pennsylvania; C+D. St. Louis, Missouri; E. San Francisco, California; F. Upper Klamath Falls, Oregon.

Each processed ERTS image represents an area 115 miles on a side. The slanting borders are due to the rotation of the Earth beneath the satellite as it passes overhead. The orientation of the satellite and its sensors is such that there is virtually no distortion of the features recorded. As a result, the images can be treated in the same manner as a road map. You will find that the scale on the image is approximately 16 miles to the inch, or 1 mile equals 1/16 of an inch. The maps provided in this work

will suffice as an introductory guide, but to do more detailed analysis of the images it is suggested that you use a current atlas. When the ERTS images are compared to the atlas, you will notice that several features which are seen on the images will not be seen on the maps, and conversely. This is due to the continual changes made to the Earth's surface by Man and Nature.

Experience has shown that the best way in which to begin your study of the ERTS image is to locate the larger features, such as lakes, rivers, mountains, and cities, shown on the included maps and the relevant images. Then, after acquiring a "feel" for the scale of the images, you can begin to find the smaller scale features. Even from 570 miles, the ERTS sensors have faithfully recorded many bridges and highways. The sections which follow are offered as introductory information to the ERTS views in question. References to specific areas on the images will be made using the grid system for ease of location of the features under discussion.

The New York - Philadelphia Corridor of Megalopolis:

During the past few decades the flight from the more depressed rural areas has decreased and the influx of new arrivals to the metropolitan has decreased correspondingly. Actually, the most recent census figures show that the nation's largest cities are decreasing in population by an average of 3% each year. At the same time, the area surrounding the cities, that is the suburbs,

continues to mushroom in their growth. The large cities play host to our great cultural, educational, manufacturing, and commercial enterprise while at the same time they suffer from vast traffic jams, high pollution counts, housing problems, and shortages of power and commodities. The first ERTS image shown depicts a section of the so-called "Bos-Wash" corridor. Reference to a map will show that most of the state of New Jersey is visible here, with lesser sections of Pennsylvania, New York, and Delaware. The total area of the scene is about 13,225 square miles. The population of the area is no less than 20,000,000 people, with the vast majority of them in and around the cities of New York and Philadelphia. All of the states seen here are old as far as the United States is concerned, so that the centers of commerce are well established. As explained previously, cities appear blue-gray in the ERTS scenes. One immediately notices the city of Philadelphia in the center of the image (F3) while New York dominates the upper right corner (A7). The 1970 census indicates that the number of people per square mile (the population density) of Philadelphia is 15,105 people per square mile, while New York is an incredible 26,674.

Place Image #5 here and Image #6 on the facing page.

By contrast, only 40 miles (2 1/2 inches) east of Philadelphia is a region of New Jersey known as the Pine Barrens (F6), an area of sandy soil, cranberry bogs, and pine forests where there is an aver-

age of 15 inhabitants per square mile. The Pine Barrens stands out as a dark, reddish-brown area, indicating considerable vegetation. The blue-gray of the cities is absent from this area, which reflects little of the influence of man. Compare, for example, the appearance of the environment along two 30 mile sections of highway. The first section is found in the Pine Barrens along Route 72 (F6), which parallels the Mullica River about 20 miles to the south of the highway. Notice that the land on either side of this highway is relatively undisturbed. By contrast, examine the congested section of U.S. 22 (B5) which exits from the dark blue (highly urbanized) Newark-Elizabeth, New Jersey region, and angles west for 30 miles to Somerville (C5). If the current trend of unplanned growth continues in this area, the population of this strip of land will simply increase, providing another classic example of urban sprawl. More serious, perhaps, is the buildup taking place along the edges of the highways leading from the Philadelphia-Camden areas to the coastal recreation center of Atlantic City (G7). The blue-gray signatures of the cities can be seen here in their embryonic stages. The danger here is to the untapped wealth of the pure ground water found in the Pine Barrens, which is equivalent to a lake 75 feet deep and covering an area of 1,000 square miles.

Historically, the cities were founded and grew alongside the natural avenues of power and transportation, that is, the Delaware, Schuyl-

kill, Lehigh, and Hudson Rivers. Today, great highway systems are used more than rivers to move the products of commerce between cities and states. By using the ERTS imagery regional planning agencies can possible avoid the mistakes made in the past when cities simply sprawled, uncontrolled, over the countryside.

Southeastern Pennsylvania:

The dominating feature of the October 11, 1972 ERTS view of Southeastern Pennsylvania is the richness of the red hue which indicates dense vegetation. The observer's attention is drawn to the upper left region of the scene by the beautiful symmetry of the ridge and valley system of the ancient Appalachian Mountains. Unlike the younger, more rugged volcanic mountains of the Western United States, the Appalachians were formed by the uplifting of coal rich sedimentary rocks. Through eons of erosional activity, the material which overlay the coal beds was gradually reduced until the coal now lies quite close to the surface. The valleys of the Blue Mountains (B4), whose waters drain into the Susquehanna, Lehigh, and Schuylkill Rivers are scarred by the effects of mining the country's richest deposits of anthracite coal. Studies of principal investigators of ERTS data show that the huge piles of silt, shale, and crushed rock, by-products of stripmining activity, can be identified as bluish-gray streaks and subsequently mapped with extreme accuracy. The stripmine spoils can be seen occupying the valleys, especially in the region

(A4). It is estimated that 16,000 acres of Pennsylvania are now covered by spoils, and that figure can only grow in the future unless positive steps are taken to reclaim the mined areas. The repetitive views provided by ERTS will aid those investigators interested in monitoring the changes which occur as a result of ongoing mining activities. The largest of the despoiled area (A4) can be seen 32 miles northwest of Reading, Pennsylvania (C5). The mines in this region produced more than nine billion tons of coal in 1971, with a commercial value of \$100 million. One consequence of the continuing energy problem, which began to cause economic havoc in the early 1970's, is the desirability to mine more of this coal as it now competes in price with the increasingly expensive foreign oil.

In addition to the abundant coal reserves, Pennsylvania has more than enough water resources to meet the needs of industry and agriculture. As the water moves out of the mountains it carries with it an appreciable load of sediments. These sediments are deposited in the great valley systems stretching from Harrisburg (D2), eastward. This fertile valley is covered by a patchwork produced by a myriad of cultivated plots (D4). Here can be found an intense concentration of vegetable, oat, tobacco, and poultry farms. To gain a better perspective of the size scale and the resolution of detail in the ERTS image, examine the region surrounding the city of Harrisburg, located 12 miles southeast

of the confluence of the Susquehanna and Juniata Rivers (C1). The spindle-shaped island found toward the Harrisburg side of the river is McCormick Island, which is only 1.2 miles long, or slightly more than 1/16 of an inch on the ERTS image. In the section F5 will be seen some of the puffy white cumulus clouds which are seen on some of the ERTS images. Because of the almost constant Sun angle in the different ERTS images, the shadows cast by mountain peaks and clouds are always in the Northwest direction. Note that the largest of the clouds seen here is about one mile in diameter.

Insert Images #7 and #8 here.

St. Louis, Missouri:

These two names tell much of this geographic region which lies in the heartland of the United States, the city's name was bestowed by its French founders in 1764, while the state's name is an older Indian word meaning "town of the large canoes". Now, by the application of modern technology, we can see this great city (E2,E5), in two differing conditions - one at peace with its cradling rivers, and the other being battered by the worst floods in history. The left portion of this split ERTS image was recorded at a time, October 2, 1972, when the Illinois, Mississippi, and Missouri Rivers were at a seasonally normal stage. The right portion, as recorded by ERTS on March 31, 1973,

shows the same rivers in a flooding stage, already over their banks though the flood wave had yet to crest. The difference in color between the two ERTS images is due to a difference in the maturity of the crops; mature in October and just being planted in March. What cannot be shown here is the loss of life, destruction of property, and the human despair caused by the flood waters. The city, colored blue-gray by the spectral mixing of the rooftops, concrete, and asphalt, is located in the lower central portion of each scene, as previously indicated. The Northernmost river (C1) is the Illinois, while the larger Mississippi (D1) enters from the left center, then turns East to meet the Missouri River. Separating the Illinois and Mississippi Rivers is the important structure known as the Dividing Ridge, which is an aid to the flood control system of the area. The Mississippi River, acting as a boundary between the states of Illinois and Missouri, flows East and turns sharply South (D2 and D5) about 15 miles North of St. Louis, where it meets the waters of the Missouri River. At the confluence of these two rivers you can see the straight blue line of the Chain of Rocks Canal (D2, D6). To the East of the Canal is the complex structure of Horseshoe Lake, which separates Granite City from East St. Louis, Illinois.

Insert Images #9 and #10 here.

The city of St. Louis, and the surrounding metropolitan area,

had a population equal to more than half of the entire state of Missouri in 1970, or approximately 2,363,000. The U.S. Census Bureau projects that almost 3 million people will inhabit the area by 1975. The pressure of these people, in terms of living, working, and recreational space, will cause further encroachment on the wooded hills to the southwest of the city, (F1, F4). The floodplain, shown as a dotted line on the map, can be examined in the October 2 ERTS image for the purpose of identifying the telltale rectangular pattern due to farming.

Farming the floodplain produces high yields due to the continual deposition of nutrient-rich silt left behind by the normal seasonal flooding of the rivers. However, the floods which occurred in the late winter of 1973 resulted in the inundation of much more than the low lying floodplain. This can be quickly corroborated by comparing the two ERTS views. Note the pale blue outline of the drowned land appearing beneath the rising flood waters in the March scene. At the time this picture was obtained the Mississippi was 38 feet above flood stage at St. Louis, the highest since 1903. More than 300,000 acres of land were already underwater at 1000, local time, and the waters were still rising.

Although the flooding itself was a disastrous event, the resulting

delay in planting time for the spring crops were to cause even more discomfort around the world. The reason is the increasing dependence of much of the world upon the United States as one of the major exporters of food.

ERTS images such as these are proving useful in the planning of flood prevention measures and in directing activities during the actual flooding emergency. Subsequent overflights of the satellite could provide data on the rate at which the flood waters are receding from the more remote areas.

The Great Central Valley of California:

The state of California with its wide variety of environments has made great use of the ERTS data. While the image of the San Francisco area shown here represents less than 9% of the state's area, it does include the coastal mountain ranges seen in section D1 and F3, a section of the 500 mile long Great Valley formed by the Sacramento and San Joaquin Valley system, and the foothills of the Sierra Nevada mountains (A7). This image was recorded on July 26, 1972 when the city of San Francisco was hidden by a fog bank (F2) produced by the cold waters which move along the California coast. The moisture laden winds from the ocean are responsible for the lush vegetation covering the Coastal mountain range.

In contrast to the richly wooded and moist slopes of the coastal range is the ridge northwest of Lake Berryessa (A1). The vegetation is not so dense, a condition due to lack of rainfall and isolation from the moist ocean air. These dry conditions are ideal for wildfires which occur with alarming frequency. A large burnt-over area can be seen as a dark gray blotch about 14 miles (B2) Northwest of Lake Berryessa. Remote sensing techniques used in conjunction with aircraft have aided firefighters in locating the hot spots of the fire which are visible through the smoke when viewed in the energy bands of the thermal infrared region of the spectrum. By concentrating their efforts on these fiercely burning areas, the firefighters have saved the lives and properties of the people living in the area.

The large body of water in the F3 section is San Francisco Bay, the site of a controversial landfilling operation. Careful examination of the southern end of the bay will show the deep blue color of the man-made salt ponds (F2), with the resultant piles of salt appearing as white dots just North of the ponds.

The blue-gray splotches on the land surrounding the bay are due to the intense urbanization the area is undergoing. The Bay shore and Nimitz freeways (F3) stand out clearly, curving around the bay like veins, thin and blue. With the intense use of the land around the bay area, the cost of the available land is so high

that it is profitable to make new land within the already congested ring. The dumping of the earth and rock into the bay for the purpose of creating dry land has been halted because of the threat to the delicate ecological balance presently existing in the bay. Should the equilibrium of the life within the waters of the bay be shifted too far, the waters would become a lifeless and foul pool.

Further inland, the reddish colors outline the agricultural region of the Sacramento and San Joaquin Valleys. During the months of July and August the amount of rainfall in this area averages 0.02 inches per month while the temperatures hover in the 90° range. Under such extreme conditions, water must be brought into the area in order to raise and maintain crops.

Insert Images #11 and #12 here.

Dissecting the Central Valley farms are miles of irrigation canals which distribute water from the Sacramento and San Joaquin River systems (D4). In the upper right corner of the image (A7) are the wooded foot hills of the Sierra Nevada mountain range. Water running off of these hills is collected in reservoirs such as the Folsom Reservoir, (A5), and stored until needed during the dry months of July through September.

Researchers can analyze the hues and location of the cultivated

lands which run diagonally through the center of this image, and then correlate their findings with ground truth studies. This technique allows scientists to quickly and efficiently identify the type of crop, the amount of land allotted to each crop, the vigor of the plants, and thus make an estimate of the expected yield. Information of this sort is vital in the assessment of surpluses and shortages of grain and food crops. The deep red of the fields in the northwest area of Sacramento (A4) are rice paddies, while the less-red areas East of the confluence of the Sacramento and San Joaquin Rivers (D5) are fields of sugarbeets and asparagus. It appears that a 4 x 6 mile bay exists at the meeting point of these two rivers. However, reference to subsequent ERTS images of the area show this "bay" to be shrinking in size. In actuality, this body of water is a flooded region due to a break in one of the levees constraining the San Joaquin River.

Before leaving the San Francisco area, we can turn our attention to the lower left corner of the scene (D1 and F3) where a long straight line can be seen along the crest of the Coast Range. This line is but a small section of the San Andreas fault system, a very active slice of the Earth's surface which produces earthquakes ranging in intensity from the devastating effects of the 1906 quake which destroyed San Francisco to daily tremors

which go unnoticed by the general public.

Southwestern Oregon - Upper Klamath Falls:

On virtually the last pass over the continental United States, ERTS scans a swath of rugged terrain cutting diagonally across the states of Washington, Oregon, and Northern California. This area comprises the geologically young region of the great Pacific Northwest. This three state region contains more than half of the standing commercial timber in the United States.

Because of the climate produced by the interaction of the moist Pacific Ocean winds and the mountain ranges of these states, conditions are ideal for growing fruits such as pears, cherries, and grapes. 100% of the raisins, more than 90% of the pears, and 24% of the cherries produced in the country come from this three state region.

Examination of the ERTS image of Southwestern Oregon clearly shows the dark red spine of the Cascade Range. The snow-capped peaks, which rise 8-9,000 feet above sea level, as well as the smaller mountains, act as a barrier to the moist winds moving eastward from the Pacific. The water which falls against the western slopes of these mountains is a very heavy contributor to the available water supply for the people living in the Willamette Valley.

are actively being timbered, the reserves of trees left, and the progress of the reforestation programs undertaken to replace the felled trees. Can ERTS help in assessing these factors? By scrutinizing the ERTS image provided here, it will be seen that the answer to this question is yes.

Mottling the entire image, most evident in section C4, are hundreds of polygons roughly 1/8 to 1/2 mile in diameter. Each small spot is an area which has been harvested of trees by the technique known as clear cutting. This method is used to hasten the regrowth of Douglas Fir seedlings which are planted by the reforestation program. Seedlings do not grow well in the shade of larger trees, thus all trees in the area where the mature fir trees are taken are felled as well. Examination of these timbered and replanted areas will indicate the growth conditions in each area, since the most recently harvested areas will show the least amount of red.

ERTS images are also useful in monitoring the growth of algae and other plants which favor lakes. Approximately 30 miles southeast of Crater Lake is found a large body of water, Upper Klamath Lake, (F7). Jutting into the lake from the Southwestern shore is a finger-like peninsula called Eagle Ridge. Approximately 1/2 mile to the East of the tip of Eagle Ridge is a small island apparently devoid of vegetation as it appears to be a

light tan. Appropriately, the island is known as Bare Island. Huge swirls of algae, appearing bright red against the blue of the lake water, can be seen along the western shore of the lake.

It is important to monitor the growth of this type of plant life as it can destroy the usefulness of lakes and ponds for recreational purposes. A good example of weed-clogged lakes are Aspen and Oatman lakes found about 10 miles south of Bare Island in the extreme right corner of the image.

How Can ERTS Images Be Used For Study?

There is so much information packed into each of the ERTS views that students of many disciplines can examine one given scene and find features of considerable interest. The list of suggested activities below is provided only as an introductory set because experience has shown that as more people examine these images, new ways to interpret them are uncovered, as well as new questions.

1. The ERTS images can be used to locate many of the features usually discussed in science and social science classes. Examples such as fall line, fault, drainage pattern, alluvial fan, wetland, river meanders and ox bow lakes, cloud forests, and many others are visible in these, and other, images.

2. Select an area seen in an ERTS image which is unfamiliar to all. Ask the students to use the image to prepare a land use map

of the area selected. Students can use color-coded keys to differentiate among the various environments such as urban, rural, suburban, wetland, agricultural, recreational, and other types of land use categories. A piece of clear acetate, or a similarly transparent material, can be used to overlay the ERTS image. In this manner, students can quickly and accurately reproduce the features chosen for study and analysis. Careful examination will allow the students to identify cities and towns, industrial complexes, farm land, dammed areas on water courses, airports, reservoirs, airports, etc. The results of the activity can then be checked against road, topographic, or state planning agency maps.

3. Choose several of the cities shown in the images with populations over 50,000 inhabitants. Ask the students to determine the area of each of the cities by measuring their sizes on the ERTS images. You might remind them that 1 inch on the image is equivalent to 16 miles. Information on the population figures can be found in any of the several almanacs available at the library. Using the information derived from the image and the almanac, the students can determine the population density. By actually determining the value for themselves, the students are now in a better position to study the sociologic significance of high versus low population density figures.

4. Locate an isolated area on any of the ERTS images. Carefully examine the area to determine something of the physical nature of the environment, i.e., arid, typically temperate, plains, mountainous. Data on wind directions, precipitation, hours of sunlight, and availability of fresh water can all be derived from climatology and geographic references. With this data in hand, ask the students to plan a community which would be in harmony with the environment, present and future, taking into consideration such things as alternate energy sources, mass transportation, and open space conservation. Surely, the differences in the environments observable, and discoverable, in the San Francisco area as opposed to the Southeastern Pennsylvania region will have an impact on the type and design of the community planned.

5. Compare the ERTS images with existing maps and note the changes which have occurred from the time the map was produced and the date appearing on the ERTS image. Students can look for features such as highways, new and proposed, tract home sites, large shopping centers, manmade lakes or lakes which have disappeared because of rerouting of streams or eutrophication, and decreases in the size of wetland areas.

6. Invite landuse managers and regional planners into the classroom to discuss how the ERTS images might be used in planning for the future.

7. Search the images for evidence of forest fire damage and determine the geographic extent of fire scar. The same thing can be done for flooded areas.
8. Locate the larger cities and ask students to relate the site of the city to the natural modes of transportation in the vicinity. Features such as highways, rivers, and natural harbors are identifiable on the images.
9. Identify stripmined areas, and determine the area of each. The values determined will probably be lower limits of the actual size because of the location of the mined areas in the valleys. You can obtain sequential views of these areas, from the sources provided in a later section, for the purpose of determining the effect of any stripmining or reclamation activities which might have occurred. The same can be done for the clear cut timbered regions in the Northwest.
10. Locate officially designated wilderness areas, national and state parks, national forests, and game refuges. These can be located on maps and then found on the ERTS images. Discuss the legal definitions of these terms and correlate the differences in the restrictions placed on the area in terms of allowable uses and the appearance of the area in terms of visible manmade changes. It is suggested that you ask state or federal officials into the classroom to talk about the letter of the law as it

applies to these different areas.

Where To Obtain Additional ERTS Images?

There are hundreds of intriguing and absorbing ERTS images available to you. The variation in the environments which exist in the United States is truly remarkable. Many students who have not had the opportunity to travel to the sea coast, mountains, deserts, and other regions can do the next best thing by examining the ERTS images of the area in question. The sources of ERTS images of different types and formats, such as prints, slide reproductions, educational packages, and transparencies are listed below.

Audio Visual Branch
Code FP
National Aeronautics and
Space Administration
Washington, D.C. 20546
Phone: 202-755-8366

NASA Headquarters Audio-Visual Branch will provide requestors with a catalog and price list which includes information on the cost of prints (black/white and color), transparencies and color slides. The NASA Headquarters photographic source can provide selected photographs on all NASA programs including ERTS imagery.

CIBA Chrome
Photo Science, Inc.
7840 Air Park Road
Gaithersburg, Maryland 20760

Persons or organizations having a transparency from which they wish to have a high quality print made can contact the above source.

General Electric Space Division
5030 Herzel Place
Beltsville, Maryland 20705
Phone: 301-345-9344

ERTS slides, prints, and transparencies may be obtained from the GE Photo Lab. Write or call the above for a listing of imagery currently available and a price list.

National Climatic Center
Federal Building
Asheville, North Carolina 28801

Earth Resources Technology Satellite (ERTS) photographs ONLY are available from this source. Write or call for price or information.

Talcott Mountain Science Center
Montevideo Road
Avon, Connecticut 06001
Phone: 203-677-1359

An educational package consisting of 39 - 35mm color slides, teacher's guide, and cassette tape is available from this source. Write or call for information on prices.

Summary:

The application of ERTS imagery to the needs of our daily lives is just now beginning, but already we can see ways in which we can coordinate our activities in a manner more conducive to symbiosis than to warfare with our environment. Your use of the satellite images will allow students to discover for themselves the reasons for controlling the growth of our world's population.

Thousands of pages have already been written about the promise of the ERTS program. The two quotes that follow are representative of what has been said.

"There can't be much question, I believe, about the general concern in this country about the quality of life; particularly about the problems of pollution, of water, of air, and of land. We are also very concerned, particularly this year, somehow, about the availability of energy sources, and natural resources throughout the world.

And we're also beginning to be concerned on a broader, national, and global basis, even, about the problem of growth of urban areas, and the impact of the industrial age on what used to be rural and wilderness areas. All of these things are of first major concerns to the informed people throughout the world. The question, of course, naturally arises, "Can ERTS help in this regard?"

..... "The answer is a resounding 'Yes'."

NASA Administrator Dr. James Fletcher
addressing the ERTS-1 symposium
March 8, 1973

"We have now reached a point where our civilization is putting tremendous pressure on the Earth's finite resources air, water, and land must be prudently managed if the civilization is to flourish rather than decay, and at our disposal we have a practical tool, remote sensing, for the

collection of the vital information needed to manage the earth resources. This is what ERTS is all about. It is the first satellite dedicated to collecting earth resources information for the benefit of mankind."

Nicholas Gramenopoulos
A Principal ERTS Investigator

GLOSSARY

B

Band - A set of adjacent wavelengths in the electromagnetic spectrum with a common characteristic, such as the visible band.

C

Color Composite Image - As associated with ERTS-1, a 9 1/2 inch color negative, transparency, or print generated from Bulk or Precision black and white triplet sets, usually using MSS Bands 4,5, and 7. The resulting colors are arbitrarily derived, hence the expression, "false color." Also called Color Additive Image and Color Infrared.

E

Electromagnetic Radiation - Energy propagated through space or through material media in the form of an advancing disturbance in electric and magnetic fields existing in space or in the media. The term radiation, alone, is used commonly for this type of energy, although it actually has a broader meaning. Also called electromagnetic energy or simply radiation.

Electromagnetic Spectrum - The ordered array of known electromagnetic radiations, extending from the shortest cosmic rays, through gamma rays, X-rays, ultraviolet radiation, visible radiation, infrared radiation, and including microwave and all

other wavelengths of radio energy.

G

Ground Truth - Information concerning the actual state of the ground at the time of a remote sensing overflight.

I

Imagery - The visual representation of energy recorded by remote sensing instruments.

Infrared Radiation (IR) - Electromagnetic radiation lying in the wavelength interval from about 7,000 angstroms to an indefinite upper boundary sometimes arbitrarily set at ten million angstroms, or 0.01 centimeters. At the lower limit of this interval, the infrared radiation spectrum is bounded by visible radiation, whereas on its upper limit it is bounded by microwave radiation of the type important in radar technology.

Infrared (IR) - Infrared radiation or pertaining to infrared radiation, as an infrared absorber.

M

Multispectral - The simultaneous use of two or more sensors to obtain imagery from different portions of the electromagnetic spectrum.

MSS (Multispectral Scanner Subsystem) - On ERTS 1 the MSS subsystem gathers data by imaging the surface of the Earth in several spectral bands simultaneously. It is a four band scanner operating in the solar reflected spectral band region from 0.5 to 1.1 micrometer wavelength. The object plane is scanned by means of an oscillating flat mirror between the scene and the double-reflector, telescope type of optical chain. The four bands are nominally referred to as Bands 4,5,6, and 7.

N

Near Infrared (B & W, color) - That portion of the electromagnetic spectrum between visible light and thermal infrared with wavelengths from .7 to 4 microns. B and W vs. color refers to the film type which is used to image in the portion of the spectrum from .7 to .9 microns.

R

Radiation - The process by which electromagnetic energy is propagated through free space by virtue of joint undulatory variations in the electric and magnetic fields in space. This concept is to be distinguished from conduction and convection. Also, the process by which energy is propagated through any medium, as in the propagation of sound waves through the atmosphere, or ocean waves along the water surface. Also called radiant energy. Also called electromagnetic radiation, specific-

ally, high-energy radiation such as gamma rays and X-rays. Radiation also refers to corpuscular emissions, such as α or β -radiation. Includes nuclear radiation and radioactivity.

RBV (Return Beam Vidicon Camera) - ERTS-1 the RBV camera subsystem contains three individual cameras operating in different nominal spectral bands, Camera 1: .475 - .575 (Blue/Green); Camera 2: .580 - .680 (Green/Yellow); and Camera 3: .698 - .830 (Red/IR.). The three Bands are nominally referred to as Bands 1,2, and 3.

Reflection - The process whereby a surface of discontinuity turns back a portion of the incident radiation into the medium through which the radiation approached.

Reflectivity - A measure of the fraction of radiation reflected by a given surface; defined as the ratio of the radiant energy reflected to the total that is incident upon that surface.

Resolution - The ability of a remote sensing system to render a sharply defined image, and including the three following terms. "Ground Resolution" - the minimum distance between two or more adjacent features or the minimum size of a feature which can be detected; usually measured in conventional distance units, e.g., feet or inches. "Image Resolution" - resolution expressed in terms of lines per millimeter for a given photographic emulsion

under specified situations. "Thermal Resolution" - image resolution" - image resolution expressed as a function of the minimum temperature difference between two objects or phenomena.

S

Sensor - The component of an instrument that converts an input signal into a quantity which is measured by another part of the instrument. Also called sensing element.

Signature - The unique reflectance or emission response from a particular object or environmental association.

W

Wavelength (symbol λ) - In general, the mean distance between maximums (or minimums) of a roughly periodic pattern. Specifically, the least distance between particles moving in the same phase of oscillation in a wave disturbance.